Stardust Navigation Covariance Analysis*

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EXTENDED ABSTRACT

The Stardust spacecraft was launched on February 7, 1999 aboard a Boeing Delta-II rocket. Mission participants include the National Aeronautics and Space Administration (NASA), the Jet Propulsion Laboratory (JPL), Lockheed Martin Astronautics (LMA) and the University of Washington. The primary objective of the mission is to collect in-situ samples of the coma of comet Wild-2 and return those samples to the Earth for analysis. Mission design and operational navigation for Stardust is performed by the Jet Propulsion Laboratory (JPL).

This paper will describe the extensive JPL effort in support of the Stardust pre-launch analysis of the orbit determination component of the mission covariance study. A description of the mission and it's trajectory will be provided first, followed by a discussion of the covariance procedure and models. Predicted accuracy's will be examined as they relate to navigation delivery requirements for specific critical events during the mission.

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Stardust was launched into a heliocentric trajectory in early 1999. It will perform an Earth Gravity Assist (EGA) on January 15, 2001 to acquire an orbit for the eventual rendezvous with comet Wild-2. The spacecraft will fly through the coma (atmosphere) on the dayside of Wild-2 on January 2, 2004. At that time samples will be obtained using an aerogel collector. After the comet encounter Stardust will return to Earth when the Sample Return Capsule (SRC) will separate and land at the Utah Test Site (UTTR) on January 15, 2006. The spacecraft will however be deflected off into a heliocentric orbit.

The mission is divided into three phases for the covariance analysis. They are 1) Launch to EGA, 2) EGA to Wild-2 encounter and 3) Wild-2 encounter to Earth reentry. Orbit determination assumptions for each phase are provided. These include estimated and consider parameters and their associated *a-priori* uncertainties. Major perturbations to the trajectory include 19 deterministic and statistical maneuvers planned for the mission. The spacecraft is three axis stabilized and has unbalanced thrusters for attitude control. Accelerations due to the attitude control system are treated stochastically.

The tracking scenario for the study is patterned after the actual schedule employed during the different phases of the mission. Conventional X-band two-way Doppler and SRA range data was simulated and the standard accuracy for these data types was assumed throughout most of the mission. However, a deweighting scheme was used for the Doppler data during times of low Sun-Earth-Probe angles, especially in the case of the DSM. Optical data is assumed to be available starting at 50 days prior to the comet encounter. The optical data will be used to improve the ephemeris of Wild-2, which is considered crucial to properly target the comet flyby.

Results of the covariance analysis are presented for all mission phases. Navigation capability will be discussed in terms of the uncertainty in the encounter B-Plane (B.R and B.T) and linearised time of flight. Delivery errors based on the final maneuver prior to the comet encounter will be presented. The most stringent navigation requirement is for the Earth reentry. The uncertainty in the flight path angle must be less than 0.02 degree (orbit determination and maneuver performance) to assure successful recovery of the SRC. Results presented show that this requirement can be met.